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Mobility-related disability three months after aged care rehabilitation can be predicted with a simple tool: an observational study

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Questions: What is the prevalence of mobility-related disability 3 months after discharge from inpatient aged care rehabilitation? Can a clinical tool predict which individuals will experience mobility-related disability 3 months after discharge? **Design**: Prospective cohort study. **Participants**: 442 patients newly admitted to two large inpatient rehabilitation units. **Outcome measures**: Predictors were co-morbidities; pre-admission mobility; and discharge cognition, pain, vision, muscle strength, and mobility. The outcome of interest was inability to climb a flight of stairs and walk 800 m without assistance. **Results**: 157 participants (36%) were unable to climb a flight of stairs and walk 800 m without assistance prior to hospital admission. Three months after discharge, 254 participants (59%) were unable to complete both tasks. A simple clinical prediction tool based on pre-admission ability to complete the two tasks, co-morbidity on admission, and pre-discharge measurement of: leaning while standing (Maximal Balance Range test), low-contrast visual acuity, and knee extension strength, had good discrimination (area under the receiver-operating characteristic curve [AUC] = 0.77, 95% CI 0.72 to 0.81, bootstrap adjusted AUC = 0.77) and was well calibrated. This tool provided substantially better ($p < 0{\cdot}001$) discrimination than pre-admission ability alone (AUC = 0.64, 95% CI 0.60 to 0.68, bootstrap adjusted AUC = 0.64). The observed risk of persisting disability ranged from 13% in those with no predictors to 93% in those with 5 predictors. **Conclusion**: Mobility-related disability 3 months after discharge from inpatient rehabilitation is common and can be predicted easily with a clinical tool. **[Sherrington C, Lord SR, Close JCT, Barraclough E, Taylor M, Cumming RG, Herbert RD (2010) Mobility-related disability three months after aged care rehabilitation can be predicted with a simple tool: an observational study. *Journal of Physiotherapy* 56: 121–127]**

Key words: Mobility limitation, Disability evaluation, Physical therapy

Introduction

The combination of physiological ageing, physical inactivity, and the additional burden of a number of pathological disease processes often culminates in disability which may manifest as an inability to live independently or to participate fully in community life.

Hospital admission for an acute medical or surgical problem in an older person may be accompanied by a persistent decline in both physical and cognitive functioning. In some people this decline leads to a loss of independence (Kortebein 2009) and in many people to a loss of the ability to complete more difficult mobility tasks. Inpatient rehabilitation services provide an opportunity to regain function (Kortebein 2009) but pressure on scarce resources may lead to people being discharged with compromised function and little opportunity to regain the higher level mobility tasks that enable an older person to re-integrate meaningfully into society.

The ability to walk 800 m and climb a flight of stairs has been used in previous studies to measure mobility-related disability (Guralnik et al 2000, Guralnik et al 1995). Inpatients in aged care rehabilitation are likely to have intermediate levels of disability. That is, they are likely to have greater mobility limitations than those who return home directly but to be more physically and mentally able than those who are admitted directly to residential care. Identification of rehabilitation patients at risk of ongoing mobility-related disability may help clinicians target provision of interventions for mobility-related disability (such as exercise programs and occupational therapy) to those who need it most. To our knowledge no models have been developed for identifying those aged care rehabilitation inpatients who will experience ongoing mobility-related disability.

Therefore the research questions for this study were:

1. What is the prevalence of mobility-related disability 3 months after discharge from inpatient aged care rehabilitation?
2. Can a clinical tool predict which individuals will experience mobility-related disability three months after discharge?

The 3-month follow-up period was chosen because we sought to investigate relatively short-term outcomes in order to guide discharge planning.

Method

Design

The study was a prospective, inception cohort study in which predictors were collected from consecutive new admissions to aged care rehabilitation units at two metropolitan public

hospitals in Sydney, Australia. Data were collected from medical records, from interviews with participants during hospital admission, and from physical tests in the 48 hours prior to discharge by a research physiotherapist (EB or MT). The order of test administration was altered to suit individual participants. The outcome of interest – mobility-related disability – was collected at three months after participants left hospital via phone calls from EB and MT and postal questionnaires.

Participants

All patients admitted to the aged care rehabilitation units between August 2005 and April 2007 were considered for inclusion in the study. They were excluded if they were deemed by the investigators or by hospital staff to be too medically unstable to complete the measurements safely or did not speak conversational English and an interpreter was not available.

Outcome measures

The predictors were: current co-morbidity, pre-admission mobility, and discharge cognition, pain, vision, muscle strength, and mobility. We chose measures that were relatively easy to use in a clinical situation, had previously been found to be predictive of falls or disability, and/or were commonly used clinically.

Co-morbidity was measured as the number of medical conditions and symptoms reported in the medical records. *Pre-admission mobility* was measured as the participant's perception of whether they could walk 800 m and climb a flight of stairs in the three months prior to the hospital admission. In the 48 hours prior to discharge from the unit, the following were measured: *cognition*, with the Mini-mental State Examination; *pain*, by asking participants to what extent they were troubled by pain; *visual contrast sensitivity*, with the Melbourne Edge Test and the low-contrast visual acuity chart (Lord et al 2003); seated knee extensor *muscle strength* with a spring balance (Lord et al 2003); and *mobility*. Discharge mobility included a range of measures. Standing balance was calculated as the sum of the durations that each of five positions (feet apart, feet together, semi-tandem stance, tandem stance and single-leg stance) could be held without assistance or arm support, with a maximum of 10 seconds (Guralnik et al 1994), and was also measured with a postural sway test (Lord et al 2003). Balance while leaning was measured with co-ordinated stability and maximal balance range (Lord et al 1996) tests. Sit-to-stand ability was measured by recording the time to complete 5 stands from a 45 cm chair (Guralnik et al 1994) and coding the level of assistance from another person and arm support needed. Stepping ability was measured using the Hill step test, ie, the number of steps onto a 7 cm block in 15 seconds (Hill et al 1996); the alternate step item from the Berg balance scale, which involves alternate placing of the feet onto a 15 cm block (Berg et al 1992); and a simple low-tech version of the choice stepping reaction time test (Lord and Fitzpatrick 2001). Gait was assessed as the time taken to stand up, walk 3 m at usual pace, turn around, return, and sit down again (Timed Up and Go Test, Podsiadlo and Richardson 1991), and as the average speed over 4 m (Guralnik et al 1994). Participants were also asked to rate their balance between excellent and poor.

The outcome of interest was inability to perform two mobility tasks – climb a flight of stairs and walk 800 m without assistance – in the three months after discharge from the unit. Each week, in the month following discharge from hospital, participants were telephoned and asked about their ability to perform the two mobility tasks. At the end of the third calendar month they were asked to complete a questionnaire that included this information and return the questionnaire in a reply-paid envelope. If a questionnaire was not returned the participant was telephoned and the information was sought verbally. The latest available measure was used in the analysis.

Data analysis

Analyses were conducted using data from the 426 participants for whom some predictor data and all outcome data were available. Missing data for predictor variables (less than 10% for all variables) were imputed using regression.

Prior to analysis we chose 15 possible predictors from those described above. This ensured there were at least 10 cases for each predictor (Peduzzi et al 1996). The choice of predictors was based on the range of scores obtained in this sample and their utility in this clinical setting. For example, we used the 7 cm step test instead of the 15 m alternate step test in the analysis as more participants were able to complete this test. Some predictors were dichotomised at the median because their distributions were highly skewed. The 15 predictor variables (and cut-offs for dichotomised variables) are given in Box 1.

Box 1. The 15 predictor variables.

1. Number of medical conditions/ symptoms
2. Participant report of being unable to complete both tasks 3 months pre-admission
3. Mini-mental score (less than 27)
4. Participant report of being troubled by pain (moderate to great extent)
5. Melbourne Edge Test score
6. Poor low-contrast visual acuity (less than 20 MAR minutes of arc)
7. Knee extension strength (kg)
8. Balance standing test time (s)
9. Poor postural sway (more than 174 mm)
10. Poor co-ordinated stability test (score of more than 60)
11. Maximal balance range test (mm)
12. Step Test inability (7 cm block)
13. Timed Up and Go Test time (s)
14. Gait speed (m/s)
15. Self-reported balance ability (poor to fair)

MAR = minimal angle of resolution

A logistic predictive model was developed. As we wished to develop a tool that was feasible for use in clinical practice, we sought to reduce the number of predictor variables without compromising predictive discrimination significantly. Simple backwards stepwise variable selection has been shown to produce overly optimistic prediction models (Steyerberg et al 2000) so we used, instead, a bootstrapped stepwise backward variable selection procedure (Austin and Tu 2004) on 1000 bootstrap samples. Those variables selected in at least 70% of bootstrap samples were retained. We also used zero-adjusted regression coefficients (Austin 2008). As logistic regression models are not easily applied in clinical settings we simplified the model by dichotomising predictors at the median integer value and unit-weighting

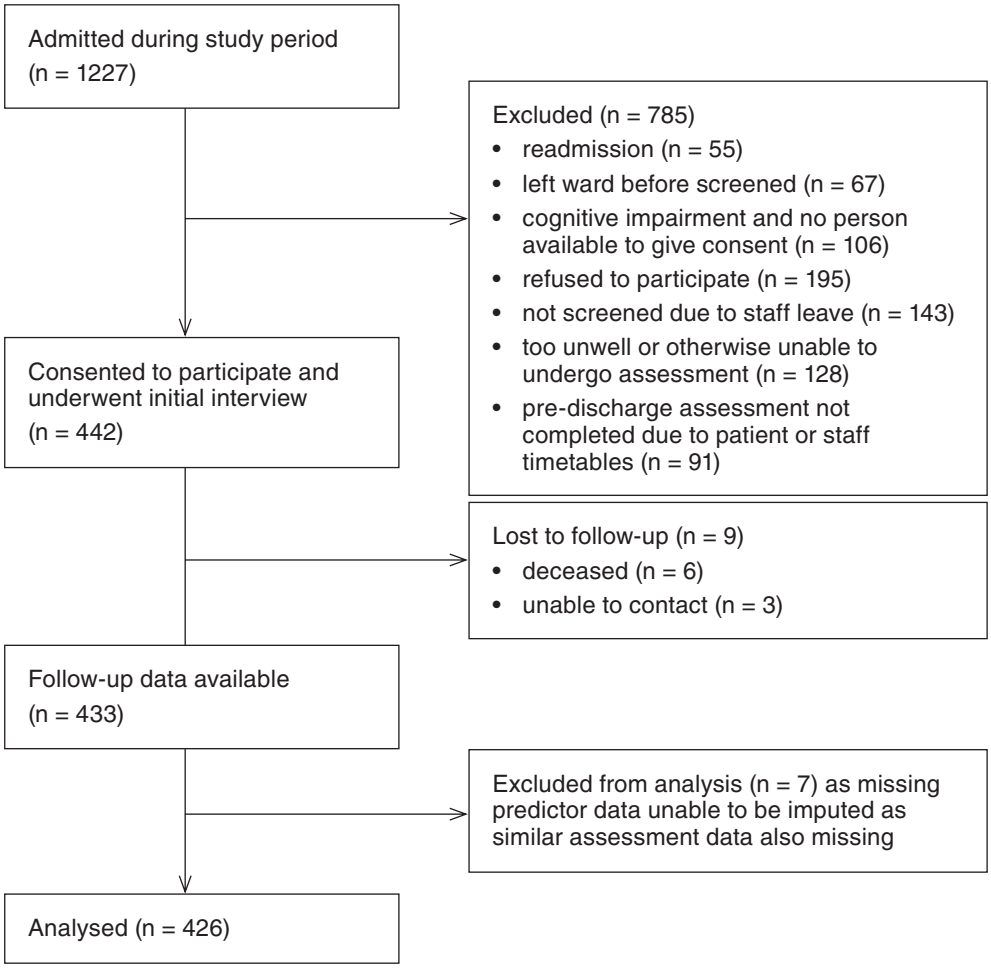

Figure 1: Flow of participants through the study.

(Schmidt 1971). We refer to the unit-weighted model as the clinical prediction tool.

The goodness of fit (ie, the extent to which predicted probabilities agreed with observed probabilities) (Harrell et al 1996) of the clinical prediction tool was then tested with the Hosmer-Lemeshow statistic. A p value of $< 0{\cdot}05$ was interpreted as indicating that the model did not fit the data. Discrimination (the ability to distinguish high-risk participants from low-risk participants) was quantified using the area under the receiver-operating characteristic curve (AUC) (Harrell et al 1996). AUCs for different models were compared using the 'roccomp' command in Stata. To ascertain the likely performance of our models in another sample (Harrell et al 1996), bootstrap adjusted AUCs were calculated using zero-corrected regression coefficients.

Results

Flow of participants through the study

Of the 1227 people admitted to the rehabilitation units during the recruitment period, 442 were included in the study. All of these underwent the initial interview. They also underwent the pre-discharge measurements, except four who were unavailable when the assessors were available. These four remained in the study. Follow-up data were collected from 433 participants. Both predictors and outcome of interest measures were available for 426 participants. Reasons for exclusion and loss to follow-up are given in Figure 1.

The baseline characteristics of the participants are presented in Table 1. The primary diagnosis was neurological for 30 (7%) people, musculoskeletal for 122 (28%), a fall in 47 (11%), and a general decrease in mobility for 86 (19%). Participants took an average of 10 medications (SD 4). Fifty-one (12%) participants were living in a low-support residential care setting (a 'hostel') prior to being admitted to hospital. There were no marked differences in participants' characteristics across the rehabilitation units. Performance on predictor variables is also shown in Table 1.

An inability to climb a flight of stairs and walk 800 m without assistance in the three months prior to hospital admission was reported by 157 (36%) participants. One week after discharge 298 (68%) participants reported being unable to complete both these tasks without assistance. Three months after discharge 254 (59%) people reported being unable to complete both tasks. Table 2 shows participants' abilities to complete each of the tasks at the various time points.

Prediction of mobility-related disability

The full 15-predictor model discriminated participants who were not able to carry out both mobility tasks without assistance at the end of follow up from those who were, with an AUC of 0.81 (95% CI 0.77 to 0.85). The bootstrap corrected AUC was also 0.81. The proportion of models on the 1000 bootstrapped samples in which each predictor was retained (p to remove of 0.20) is shown in Table 3.

Table 2. Number (%) of total participants who could not perform mobility tasks 1 week and 3 months after discharge by pre-admission ability.

Pre-admission ability (n = 442)[a]	1 week after discharge (n = 436)[b]			3 months after discharge (n = 433)[c]		
	Unable to do stairs n = 306 (70)	Unable to walk 800 m n = 379 (87)	Unable to do both tasks n = 298 (68)	Unable to do stairs n = 262 (61)	Unable to walk 800 m n = 322 (74)	Unable to do both tasks n = 254 (59)
Climb a flight of stairs without assistance						
Unable n = 167 (38)	146 (48)	160 (42)	146 (49)	130 (50)	143 (44)	126 (50)
Able n = 275 (62)	160 (52)	219 (58)	152 (51)	132 (50)	179 (56)	128 (50)
Walk 800 m without assistance						
Unable n = 247 (56)	196 (64)	230 (61)	193 (65)	171 (65)	204 (63)	168 (66)
Able n = 195 (44)	110 (36)	149 (39)	105 (35)	91 (35)	118 (37)	86 (34)
Complete both tasks without assistance						
Unable n = 157 (36)	138 (45)	151 (40)	138 (46)	122 (47)	136 (42)	119 (47)
Able n = 285 (64)	168 (55)	228 (60)	160 (54)	140 (53)	186 (58)	135 (53)

[a]reported on interview soon after admission, [b]reported during phone call median 7 days after discharge, [c]reported with phone call or postal questionnaire median 92 days after discharge

Table 1. Characteristics of participants.

Characteristics on admission	Participants (n = 442)
Age *(yr)*, mean (SD)	82 (8)
Gender, n women (%)	313 (71)
Co-morbidities (n), mean (SD)	8.3 (3.2)
Pre-admission mobility, n unable to do both tasks (%)	157 (36)
Characteristics on discharge	**Participants (n = 438)**
Mini-mental score, n less than 27 (%)	248 (57)
Troubled by pain (moderate to great extent), n (%)	177 (40)
Melbourne Edge Test score *(0 to 24)*, mean (SD)	18 (4)
Low-contrast visual acuity, n < 20 MAR minutes of arc (%)	222 (51)
Knee extension strength *(kg)*, mean (SD)	13 (6)
Balance standing test *(s)*, mean (SD)	23 (9)
Postural sway, n more than 174 mm (%)	221 (50)
Co-ordinated stability test, n score > 60 (%)	219 (50)
Maximal balance range test *(mm)*, mean (SD)	90 (45)
Step Test (7-cm block), n unable (%)	159 (36)
Timed Up and Go Test *(s)*, mean (SD)	32 (18)
Gait speed *(m/s)*, mean (SD)	0.59 (0.25)
Self-reported balance ability (poor or fair), n (%)	262 (60)

MAR = minimum angle of resolution

Five variables were retained in more than 70% of models on bootstrapped samples. The AUC for the 5-predictor model was 0.79 (95% CI 0.75 to 0.84). The difference between the AUCs for this model and the full 15-predictor model was not statistically significant (p = 0.08). The zero-corrected odds ratios for individual variables in the 5-predictor model are shown in Table 3.

To facilitate the use of the prediction model in busy clinical

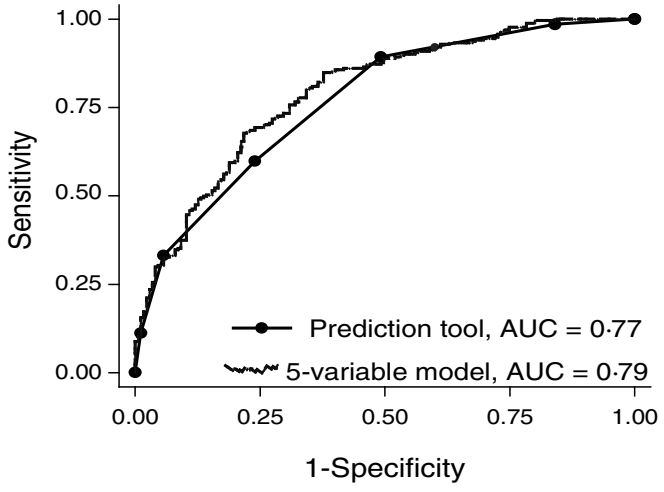

Figure 2. Receiver-operating characteristics for the 5-variable model and the unit-weighted clinical prediction tool. AUC= area under the curve.

Table 3. Mean (SD) and proportions with impairments on predictor variables among those who were and were not able to walk 800 m and climb a flight of stairs three months after leaving inpatient rehabilitation.

Variable	Unable to do both tasks n = 251	Able to do both tasks n = 175	% of bootstrapped samples in which predictor retained[a]	Odds ratios[b] for the multivariate model[c] 95% CI
Number of medical conditions/ symptoms, mean (SD)	9.0 (3.0)	7.3 (3.1)	97	1.18 (1.00 to 1.24)
Maximal balance range (*mm*)	78 (40)	110 (44)	95	0.99 (0.98 to 1.00)
Poor low-contrast visual acuity (less than 20 MAR minutes of arc)	154 (61)	62 (35)	91	2.00 (1.00 to 3.58)
Inability to complete both tasks 3 months pre-admission	119 (47)	33 (18)	87	2.04 (1.00 to 3.91)
Knee extension strength (*kg*)	12.1 (5.1)	15.1 (6.6)	77	0.96 (0.91 to 1.00)

[a]Backwards stepwise selection with p to remove of 0.2 applied to each bootstrap sample, [b]Odds ratios are zero-corrected i.e. an odds ratio of 1 is allocated for models on the bootstrapped samples in which the variable does not appear, [c] Variables retained in > 70% of 1000 bootstrapped samples. Variables retained in < 70% of bootstrapped samples were: Melbourne Edge Test score (63%), Step Test inability (55%), Timed Up and Go Test (s, 53%), Gait speed (m/s, 48%), Poor co-ordinated stability test (> 60, 40%), Mini-mental score (< 27, 31%), Balance standing test time (30%), Self-reported balance ability (poor to fair, 28%), Troubled by pain (moderate to great, 24%), and Poor postural sway (> 174 mm, 24%), MAR = Minimum angle of resolution.

settings, we constructed and tested a unit-weighted clinical prediction tool with continuous predictors dichotomised at their median integers. Probability of mobility-related disability (inability to climb a flight of stairs and walk 800 m without assistance) three months after discharge from aged care rehabilitation was predicted by the number of the 5 predictor variables shown in Box 2.

Box 2. Clinical prediction rule and accuracy of prediction for mobility-related disability 3 months after discharge from aged care rehabilitation.

Predictors

More than 8 medical conditions or symptoms

Impaired leaning balance (Maximal Balance Range test score < 88 mm)

Poor low-contrast visual acuity (< 20 MAR minutes of arc)

Poor leg muscle strength (knee extension < 12 kg)

Pre-admission inability to complete the two tasks

Clinical Prediction Rule

Probability of mobility-related disability 3 months after discharge from aged care rehabilitation

= 16% in the presence of 0 predictors

= 32% in the presence of 1 predictor

= 53% in the presence of 2 predictors

= 74% in the presence of 3 predictors

= 87% in the presence of 4 predictors

= 94% in the presence of 5 predictors

Accuracy of prediction

Area under the curve = 0.77

MAR = minimal angle of resolution

Unit weighting (replacing regression coefficients with values of 1) makes calculation of prediction scores easy because with unit weighting the prediction score for any person is just the count of the number of predictors that person has. The AUC for this tool was 0.77 (95% CI 0.72 to 0.81) which is significantly lower than the AUC for the 5-variable model ($p = 0.03$) but large enough to be clinically useful. The receiver-operating characteristic curves for the 5-predictor model and the unit-weighted clinical prediction tool are shown in Figure 2. The tool provided substantially

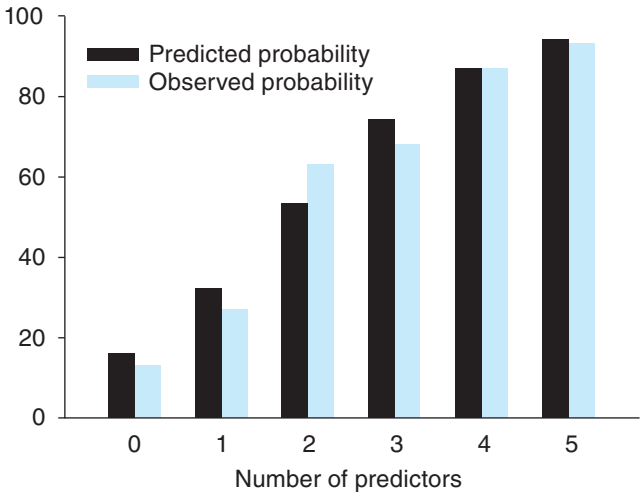

Figure 3. Predicted (black) and observed (blue) probability of being able to walk 800 m and climb a flight of stairs three months after discharge, by number of predictors (n = 426). Predictors are: > 8 medical conditions or symptoms, impaired leaning balance (Maximal Balance Range test score < 88 mm), poor low-contrast visual acuity (< 20 MAR minutes of arc), poor leg muscle strength (knee extension < 12 kg), and pre-admission inability to complete the two tasks. 32 participants had no predictors, 84 had one predictor, 118 had two predictors, 99 had three predictors, 63 had four predictors and 30 had 5 predictors.

better ($p < 0{\cdot}001$) discrimination than pre-admission ability alone (AUC = 0.64, 95% CI 0.60 to 0.68, bootstrap adjusted AUC = 0.64).

Figure 3 shows the predicted and actual probabilities of reporting an inability to walk 800 m and climb a flight of stairs at the end of the follow-up period for each score on the clinical prediction tool. Predicted risks for lasting disability ranged from 16% in those with no predictors to 94% in those with five predictors. Observed risks for mobility-related disability at three months ranged from 13% in those with no predictors to 93% in those with five predictors. Inspection of actual and predicted probabilities indicated an acceptable level of agreement between actual and predicted probabilities (Hosmer-Lemeshow $p = 0.07$).

Discussion

This study found that the majority of people (59%) who had undergone an inpatient aged care rehabilitation program were unable to climb a flight of stairs and walk 800 m three months after discharge. The inability to complete the tasks could be predicted with reasonable accuracy (AUC = 0.77) by a brief assessment of five factors: pre-admission ability to complete the two tasks, co-morbidity on admission, and pre-discharge measurement of leaning while standing (Maximal Balance Range test), low-contrast visual acuity, and knee extension strength.

In our experience, clinicians sometimes assume that the main predictor of discharge ability is pre-admission ability. Of the 157 participants who reported being unable to complete both tasks prior to hospitalisation, 152 had 3-month data available. Of these, 33 (22%) reported being able to complete both tasks three months after discharge. The present study confirmed that pre-admission abilities were a strong predictor of outcome but also found that the 5-item clinical prediction tool had significantly better discrimination for 3-month outcome than pre-admission ability alone.

The primary limitation of the present study was the short follow-up period. It is not clear if mobility-related disability would undergo further systematic changes after three months and whether different variables would predict longer term mobility-related disability. In addition, different predictors may have been found if different tests of physical performance had been used. Another limitation was that we recruited less than half of the potentially eligible people admitted to the rehabilitation units. It would, however, appear unlikely that the reasons for lack of involvement in the study (eg, staff leave, lack of availability of a carer to give consent for some of those with cognitive impairment) would have resulted in a serious selection bias. However, generalisability of the results to people undergoing aged care rehabilitation in other settings is reasonable, given that the recruitment was from two rehabilitation units in different geographical locations.

We used contemporary statistical methods to internally validate the clinical prediction tool. These methods reduce the tendency for variable selection procedures to produce overly optimistic estimates of model performance. Nonetheless it remains to be shown how well the clinical prediction tool performs in settings other than those used in the current study (Moons et al 2009). That is, the prediction tool now needs to be validated externally.

The tool we have developed enables the absolute risk of persistent mobility-related disability to be calculated. Predicted risks for lasting disability ranged from 16% in those with no predictors to 94% in those with five predictors. This approach has the potential to be more clinically useful than a tool that simply determines whether an individual is or is not at an increased risk.

Predictions of ongoing mobility-related disability in those who are being discharged from rehabilitation settings could have a number of important uses. Prognostic information could be given to patients and their carers to enable better preparation for the amount of ongoing assistance that is likely to be required. Similarly, this information could be used by service providers to arrange services such as assistance with shopping and transport for medical care and social events. These services have the potential to enable older individuals with mobility-related disability to continue living independently at home.

Predictions of mobility-related disability after rehabilitation might also be used to target provision of ongoing rehabilitation services. The individual who is predicted to be able to walk longer distances and manage stairs without assistance could be targeted for interventions designed to prevent falls when mobilising in the community. Conversely those who are predicted to have ongoing mobility-related disability could be targeted for intensive intervention designed to alter the outcome. Clinical trials have found that exercise programs in older people can increase walking distance (Sherrington et al 2008) and enhance stair climbing abilities (Hauer et al 2003), and training in outdoor mobility has been found to enhance community ambulation in people after stroke (Logan et al 2004).

In summary, this study found that in people who have undergone inpatient rehabilitation, ongoing mobility-related disability is common and can be predicted with a high degree of accuracy with a simple tool. This information can be used not only to identify people most at risk, but also to identify need for service provision and tailor intervention to minimise disability. ■

Ethics: The study was approved by Human Research Ethics Committees at the University of Sydney and the two participating hospitals. Informed consent was sought directly from all eligible patients with a Mini-mental State Examination score (Folstein et al 1975) of ≥ 24/30. For those with lower scores, consent was sought from the patient and the person responsible (usually a family member). Written consent was obtained before the study began.

Competing interests: SR Lord is a company director of Balance Systems Inc, which makes equipment items used in the assessment (knee extension strength, maximal balance range, and low-contrast visual acuity) which are commercially available through the Prince of Wales Medical Research Institute. All other authors have nothing to declare.

Support: This study was funded by the New South Wales Health Department. C Sherrington, SR Lord, and RD Herbert are funded by Australian National Health and Medical Research Council Fellowships.

Acknowledgements: Professor Susan Kurrle and Dr Anne

Tiedemann assisted with study design and set-up, and Connie Severino and Sandra O'Rourke entered data.

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